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Enhancing sustainability in municipal solid waste management: An Anaerobic-based scenario for Kaunas MBT

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Abstract. The Mechanical-Biological Treatment (MBT) facility plays a vital role in the management of municipal solid waste (MSW). A Life Cycle Assessment of the current operations at the Kaunas MBT reveals that the facility processes have a negative environmental impact. This impact can be minimized by reducing the carbon footprint. This study presents the activities of the MBT in the Kaunas Region, Lithuania, and proposes a scenario to reduce the carbon footprint of the Kaunas MBT. The Kaunas MBT processes waste collected from four different municipalities in the Kaunas region. The MBT residues are disposed in two landfill sites for non-hazardous waste. Biodegradable waste is composted using an aerobic technique inside composting tunnels, and afterward, the composted material is used in landscaping. Refuse-Derived Fuel (RDF) produced by the MBT is transferred to the Kaunas incineration plant for energy production. This article proposes a scenario to replace the aerobic composting of biodegradable waste at the MBT with anaerobic digestion to produce biogas. This biogas can be used to generate electricity, meeting the energy demands of the MBT facility. As a result, the Kaunas MBT facility could be considered a Green MBT. This facility requires a load of 2.2MW to operate smoothly, consuming 19.27 million kWh annually. If the MBT is modified according to aforementioned proposed scenario, 72240 tons per year of biodegradable material can generate 87.70 million kWh annually.

1. Introduction

Municipal solid waste (MSW) is getting more attention from the international policymaking institute because with population growth, development of economy and urbanization worldwide significantly increase generation of total MSW [1].According to data published by the World Bank, total MSW generation would climb to 340 million tonnes in 2050[2]. Inappropriate and unprofessional waste management systems of any country can expose waste to the atmosphere as a consequence of the aforementioned interaction of waste to atmosphere has a significant likelihood for human health and environment. Continually and significantly growth of waste in household, industrial, and commercial sectors makes it one of the most renewable source to generate energy from waste, material, fuel and other by-products with higher-value [1]. Most of the countries, municipal solid waste still being treated via incineration and landfill, however, many lower-income countries are trying to promote separate collection and disposal of waste such as organic waste from household and food industry, combustible waste and other waste, but not achieve goals according to regulations and environmental protection department

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[3]. In waste management systems, the separation of waste is very pivotal; efficient separation techniques such as mechanical and manual increase recycling efficiency reduce waste for landfill and enhance circular economy [4]. It is hard to establish stable operating conditions for organic waste treatment approaches, such as anaerobic digestion, because an extensive number of waste types are mixed in with organic matter. The implementation of mechanical-biological treatment (MBT) systems can provide a way forward in this situation. MBT plants combine biological stabilization of organic matter through procedures like anaerobic digestion or composting with mechanical separation of various waste kinds found in MSW. These facilities are designed to collect recyclables from mixed waste streams and to separate the garbage that breaks down quickly[3][5].

2. Methodology and Material

2.1 Methodology

This study begins with the collection of information and data about the municipal solid waste of Lithuania. To understand MSW management, authors did a literature review and analyzed the report published by the Association of Lithuanian regional waste management centers and also visited different sorting stations in Kaunas and MBTs of Kaunas, Marijampole, and Alytus waste management regions of Lithuania. The focus area in this study is Kaunas MBT. In Kaunas MBT, after mechanical treatment of waste, biodegradable waste is being composted by using aerobic tunnels. After a literature review, areas of improvement were identified, and a proposed scenario was developed for Kaunas MBT. The framework of the methodology is illustrated in Figure 1

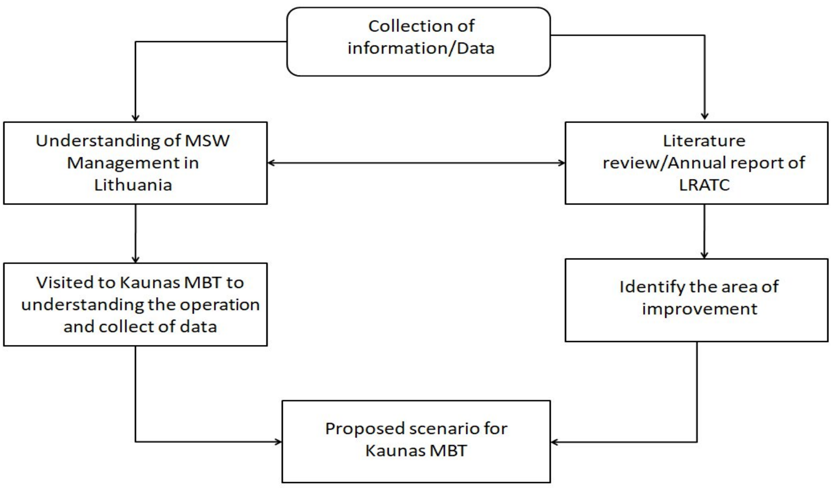

Figure 1 Framework of methodology.

3. Results

3.1 Municipal waste generation and treatment in Kaunas

Lithuania is located on the eastern shores of the Baltic Sea, covering an area of 26,173 square miles, and the largest among three Baltic States. Lithuania has ten different waste management regions such as Alytus, Kaunas, Klaipėda, Marijampolė, Panevėžys,Vilnius, Utena, Telšiai, Tauragė and Šiauliai. Each region is subdivided into different municipalities for administration as well as waste management. The estimated population of Lithuania is 2.88 million. Kaunas waste management region includes the next municipalities like, Kaunas city municipality, Kaunas district municipality, Kaisiadorys district municipality, Jonava district municipality, kedainiai district municipality and Raseiniai district municipality [6]. In 2022 the amount of municipal waste generated accordingly in the region (Kg/Capita) can be observed in figure2. Waste generated by each inhabitant in the Kaunas region is 411 kg/ capita. The average municipal waste generated in the year 2022 by a citizen was 448 Kg, which is actually under the estimated value for EU 505kg/capita. The waste management structure of the Kaunas comprises 14 large-scale collections sites, three composting sites, and two mechanical-biological facilities without biogas extraction, two landfills for non-hazardous waste, and 14 landfills monitoring tools[7]. Scientists forecast that 268476 tonnes of waste could be generated in the Kaunas region in the near future[8].

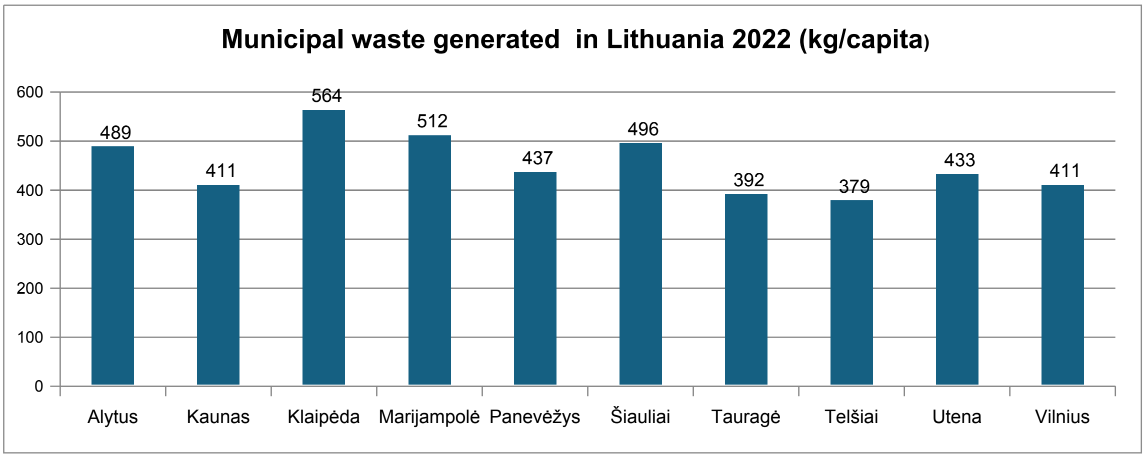

Figure 2. Municipal waste generated in various waste management regions of Lithuania in 2022 (kg/capita).

By substantially raising the capacity for treatment of mixed municipal garbage, including both mechanical biological treatment (MBT) and incineration (with energy recovery), Lithuania was able to decrease its dependency on land-filling. The capacity of garbage incineration increased from 255000 tonnes annually to 615000 tonnes annually in 2020 with the opening of two additional incineration plants in Vilnius and Kaunas. As a result, incineration increased to 25.9% in 2020, while the landfill rate decreased from 29.8% in 2016 to 16.3%. Since 2013, untreated garbage has been prohibited from being land-filled, and hence a sizable portion of MBT outputs is currently included in land-filled waste[9].

3.2 Present operational activities of Kaunas MBT.

The europian union makes responsible all its member states national government to adhere to the directives recommended by the EU regarding wste management. These governemts are obligated to legislate accordance with the directives to ensure significant waste management. The EU has developed a framework for waste management, which includes the implementation of six directives [10]. Similarly waste management system of Lithuania working according to framework of EU. Municipal waste management in Lithuania is organized by municipalities. In Kaunas waste management region inhabitants brings their waste to container sites for collection of mixed waste and secondary raw materials. From collection points solid waste transport to MBT through heavy vehicles. In side the MBT bulk waste is first mechanically treated to reduce it size and separate into different frictions according to its properties, every day approximately 500 tonnes waste processed in Kaunas MBT facility.[7]. There are two shredders in Kaunas MBT, shredding is essentail to make the process efficient, principally in shredding process a rotating equipment with sharp blades to crush materials and reduce size of material [11]. Waste in bulk amount fed into the shredder and after fed into drum separator, which is also an essential element of mechanical biological treatment process. It hepls to processes efficient way to separate material based on their physical and magnetic properties [12]. 4% of outcome from each drum separator return back to shredder, 32% goes to magnetic separator before the biological treatment/aerobic composting tunnels and 65% of the waste from drum separator passed through the balistic separator. In MBT technology balistic separatorefficiently segregates wastes based on respective shape and size also making the separation process effective and increase resource recovery [13]. 21% small fraction of bioligicalwasteoutcome from each balistic separator goes to magnetic separator before the aerobic composting tunnels, 39% 2D fraction such as paper, cardboard, plastic packaging and lightweight waste from each balistic separator goes to Near Infrared Separator (NIR) for paper and cardboard separation and remaining 40% 3D fraction such as bottles cans, woods and other solid waste goes to magnetic separators. From magnetic separators 2.6% ferrous waste/packaging eleminated and remaining 3D waste 97.4% goes for Non-ferrous separator, at this stage Non-ferrous waste 1.2% eleminated from each separator and remaing 98.8% 3D waste processed in next equipment to segregate the PET, HDPE, LDPE and other mixed plastic waste[7]. Figure 3a and 3b explain the present and proposed scenarios for Kaunas waste management region. In Kaunas MBT after mechanical process biodegradable waste send to composting tunnels for aerobic decompostion.

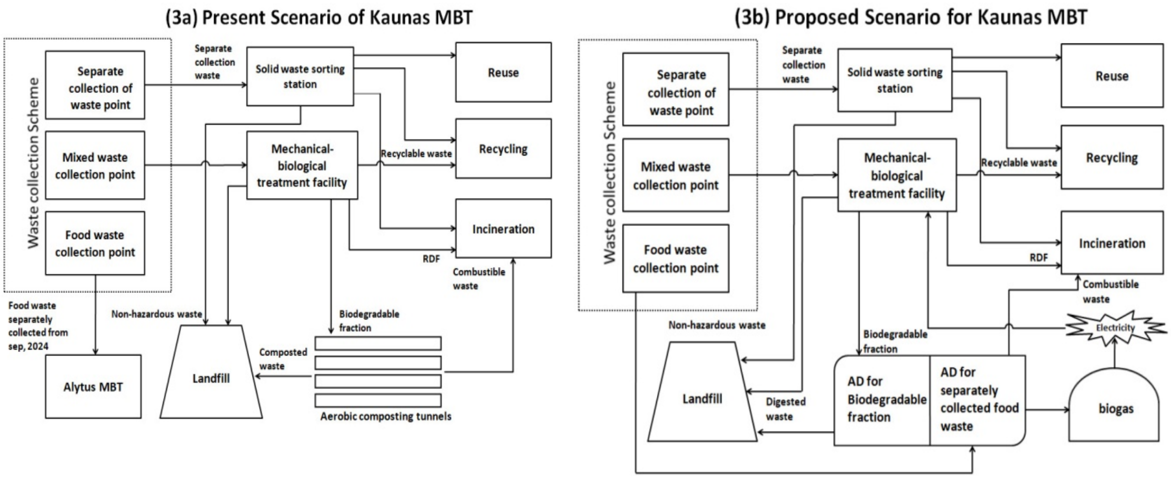

Figure 3a &3b. Schematic explanation of the present scenario for Kaunas waste management region and schematic explanation of the proposed alternative scenario.

3.3 Proposed scenario for Kaunas MBT

According to mass balance provided by Kaunas MBT administartion about 50-53% biodegradable waste being treated in biological treatment facility. From september 2024 in kaunas region municipalities have started collection of food waste separately, in present scenario separately food waste is being sent to Alytus region MBT for anaerabic composting and production of biogas. In proposed scenario for Kaunas region MBT, it is suggested that biodegradable fraction and separately collected food waste would treated in anaerobic condition means in decompostion in the absence of oxygen and produce biogas. Energy crops continue to be the predominant feedstock used in the year 2018 (about 35–38% of the net

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primary energy product from the EU biogas), subsequently followed by livestock manure (33%), municipal solid waste (17%), agricultural residues, as well as sequential crops (roughly 6-9%), and sewage (6%)[14]. One mertic tonne of organic waste can decay and discharge 50-110m^3 of CO_2 and 90-140m^3 of CH_4 into the environment. On the contaray, if the same biodegradable solid waste process into anaerobic digestion conditions its produce biogas as a result the adverse impact on the environment will be decrease and there will be less reliance on fossil fuels [15]. Previuos studies shows that 470m^3 of biogas per ton of household organic waste matter can produces, primarily it is evident from scientific results that biogas contains 57.35% methane gas. Methane production per ton of solid waste about 216.7m^3/t and heating value of methane is 5.70kWh/m^3. Based on this, the primary energy production from one tonne of household waste will be 1235.27kWh[16]. According to the data from Kaunas MBT, equipment with load of 830.7kW is installed for the mechanical activities, whilefor the biological and refining activities loads are 1182.75kW and 114.15kW, respectively. Annually 19.27 million kWh of energy require to operate installed equipment in Kaunas MBT. From the year 2018 to 2022, an average of 63,474 tons of biological waste has been composted annually at the kaunas MBT [7].

3.4 Key Findings

This study proposed a scenario for Kaunas MBT, this study analyzed that if biological waste about 50-53% from mechanical section of MBT is treated anaerobically instead of aerobic condition, this proposed idea have potential to produce enough biogas that could be used as fuel to generate electricity. In the future, Kaunas MBT facility could receive a total of 268,476 tons of waste approximaltely for biological processing including 139,607 tons of biological waste is treated anaerobically, it has potential to produce 30.25 million cubic meter of methane gas annually. Furthermore, this gas can be used to geneate electricity, with a potential of 172.44 million kWh per year. The separate collection of food/kitchen waste has been initiated by the municipalities of the Kaunas region starting from September, 2024. There is no information provided yet by the concerned department regarding the efficiency and data of aforementioned separate collection waste. However, in the future when the separately collected food waste is anaerobically decomposed according to the proposed scenario, it will have significant impact on biogas production.

4. Conclusions

The activities taking place within the Kaunas MBT are themselves astrive to improve the environmental conditons. Within the MBT, operation is carried out with the intention of disposing of waste in an efficient and responsible manner. With positive intentions one important aspect to consider is the life cycles of processes and it environment impact, similarly the processes within the MBT also have certains impacts. This is because the equipment installed within the Kaunas MBT requires 87.70 million kWh of energy to operate, and the carbon footprint of energy production is included in the life cycle impact (LCI). However, carbonprint can be reduced if the proposed scenario is implemented. By decomposing biological waste under anaerobic conditons instead of aerobic conditions to generate biogas which contains about 55-60% methane gas, this methane gas used as fuel in gas engine to produce electricity and this electricity is utilized within the respective MBT. As a result of this Kaunas MBT could be considered a green and sustainable MBT.

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